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ENZYME ACTIVITY IN RELATION TO TOTAL K, Ca, Mg, Fe, Cu AND Zn IN THE OIL PALM RHIZOSPHERE OF RIAU'S PEATLANDS, INDONESIA

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ABSTRACT

Enzyme activity can be used as a peat decomposition indicator in the oil palm rhizosphere of peatlands. Oil palm plantation management requires fertilization in the rhizosphere to provide nutrients for oil palm growth. The state of total nutrient in the rhizosphere can influence enzyme activity. This research aimed to study enzyme activity in relationship to nutrients in the oil palm rhizosphere of peatlands. Using the explorative method in Riau's tropical peatlands, an oil palm plantation was chosen as a location for the main sites, and a degraded forest as well as a shrubland were chosen as comparison sites. In the oil palm plantation, peat samples were taken from peats adhering to oil palm roots at the peat depths of 0–25 and 25–50 cm and at distances of 0–1, 1–2, 2–3, and 3–4 m from the trees. In the degraded forest and shrub, t samples were taken from selected plant roots at the depths of 0-25 and 25-50 cm. The triplicate peat samples were then composited for an analysis of enzyme activity and total nutrient content. Results showed that enzyme (urease, phosphatase, β-glucosidase, and laccase) activity in the oil palm rhizosphere decreased as the distance from trees and the depth of rhizosphere increased. The decline in enzyme activity was caused by a low peat pH and an increased water content as well as organic carbon content. Enzyme activity increased with increasing oil palm age and ash content. Total K and Zn contents showed no correlation with enzyme activities. However, total Ca and Mg contents showed positive correlation only with β-glucosidase activity. Total Fe and Cu contents showed significantly negative correlation with enzyme activities (urease, phosphatase, β-glucosidase, and laccase). Enzyme activity in the rhizosphere of the degraded forest and shrubs were mostly lower than in the oil palm rhizosphere.

Keywords: enzyme activities, oil palm, peatland, rhizosphere, total nutrients

INTRODUCTION

In Indonesia, as much as 1.7 million ha of peatland has been cleared for oil palm plantations, of a total peatland area of 14.9 million ha (Tropenbos International Indonesia 2012; Ritung *et al.* 2011). The change in peatland use due to oil palm cultivation has become a spotlight as it is considered to be a source of CO_2 emissions due to land drainage and therefore accelerated peat decomposition as well as peat fires during extended dry periods. The relationship between accelerated peatland decomposition due to land drainage and the development of oil palm cultivation is still debatable.

The influence of oil palm cultivation can be traced by studying enzyme activities in the roots or in the rhizosphere. Peat properties, like pH, can influence the application of fertiliser for oil palm growth. A change in pH can influence certain biochemical reactions, such as enzyme activity in peatlands. Rhizosphere is one environment that is influenced by the interaction between plant roots and peat matter. All enzyme activities in the rhizosphere result in changes in soil properties and processes. These changes then determine the availability of nutrients,

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which is determined by enzymes released by roots and microorganisms (Gianfreda 2015). Enzyme activity is highly responsive to environmental changes caused by changes in the atmosphere's CO_2 concentrations and rainfall patterns, which in turn impacts ecosystem functions, such as decomposition, nutrient cycles, and plant-microbial interactions (Burns *et al.* 2013).

Several enzymes, such as urease, phosphatase, ß-glucosidase, and laccase can be used as indicators for organic matter decomposition processes in peatlands. The enzyme often used as an indicator for organic carbon mineralization in the soil is β-glucosidase (Stott *et al.* 2010). Common enzymes that hydrolyse molecules, such as hydrolase activity (urease, phosphatase) and phenol oxidase (involved in the synthesis of secondary compounds, decomposition, and humification), need to be given great attention because these enzyme activities are essential in nutrient release (Nannipieri *et al.* 2012). It is known that K, Ca, Mg, Fe, Cu, Zn in the soil are nutrients involved as enzyme cofactors mostly administered in fertiliser. Enzymes require metal ions as catalysts in biochemical reactions. Transition metal ions are an essential requirement in biochemical functions, as evidenced by the fact that metalloproteins represent about one third of all structurally characterized proteins with biological activity (Finney & O'Halloran 2003). This study aimed to assess enzyme activity in relation to total nutrients in the oil palm rizosphere of peatlands in the Riau Province, Indonesia.

MATERIALS AND METHODS

The research was conducted on peatland, at an oil palm plantation in the Pangkalan Pisang Village, Koto Gasib, Siak District, Riau Province, Indonesia (0.74-0.77N and 101.77-101.74E). The peatland had a groundwater table in the range of 40 cm in the rainy season and 80 cm in the dry season.

Peat material analysis was carried out at the Laboratory of Soil Chemistry and Fertility, Department of Soil Science of Land Resources, Bogor Agricultural University (IPB), Bogor. The research was an explorative study in the form of observation activity (observational exploratory research). Sites were selected based on peat thicknesses of <3 and >3 m and oil palm age of <6, 6-15, and >15 years. Observations were done on six transects at the oil palm plantation and one transect in the respective degraded forest and shrub, in which each transect is perpendicular to the drainage channel (collection drainage system).

Rhizosphere observation and peat sampling were done by dismantling the root zone of the selected oil palm tree's frond windrow, the space between two rows of plants. Samples were taken twice in the wetter months (January-February 2015) and dryer months (July-August 2015). Peat samples were composited from peat adhering to root surface. Peat samples were dug on peat layers at the depths of 0-25 and 25-50 cm, and at distances of 0-1, 1-2, 2-3, 3-4 m from the tree within a quarter circle area (¼ circle of canopy). The application of macro and micro nutrient fertilizers (K, Ca, Mg, Fe, Cu, Zn) and mineral-soil dressing in the oil palm circle at a distance of 1-2 m, about 30-cm, turned into benchmark changes that occurred in the oil palm rhizosphere on peatlands (Fig. 1 and Table 1). Fertiliser application was done every 4 months and mineral-soil dressing containing 6.1% Fe or 610 mg/kg (Hartatik 2012) as an ameliorant was given one time (±100 kg/tree) in the period between rainy season and dry season. For comparison, samples were also collected from root zones of the degraded forest and shrub vegetation. The samples were taken at the distances of 50 and 100 m from the collection drain (drainage canal) at the depths of 0-25 and 25-50 cm from the peat surface. Adhered samples were collected from selected plant roots.

Table 1 Total K, Ca, Mg, Fe, Cu and Zn (kg/tree) contents applied by the oil palm plantation management[a]

Oil palm age (years)			Oil palm age (years)		
<6	6-15	>15	<6	6-15	>15
2 (K); 0.8 (Ca) and 0.2 (Mg)	-	-	-	-	-
nd[b]	11(K); 2(Ca) and 0.7(Mg)	-	nd	0.04(Fe); 0.04(Cu) and 0.04 (Zn)	-
nd	nd	10(K); 3(Ca) dan 1 (Mg)	nd	nd	0.04(Fe); 0.04(Cu) and 0.04 (Zn)

Note: [a]The total nutrients (K, Ca, Mg, Fe, Cu and Zn) were given using fertilisers (compound fertilisers, Kieserit, NK, Dolomite, Calcite, MgSO,$FeSO_4$, $CuSO_4$, $ZnSO_4$) for oil palm aged <6, 6-15, >15 years; the fertilisers were used at reasonable rates as recommended for plantations, and applied by the plantation management during the 2002-2015 period (K, Ca, Mg) and the 2011-2012 period (Fe, Cu, Zn).
[b]nd = no data; the fertilisers were also administered by plantation management at a reasonable rate prior to 2002; however, the application of fertiliser was not documented.

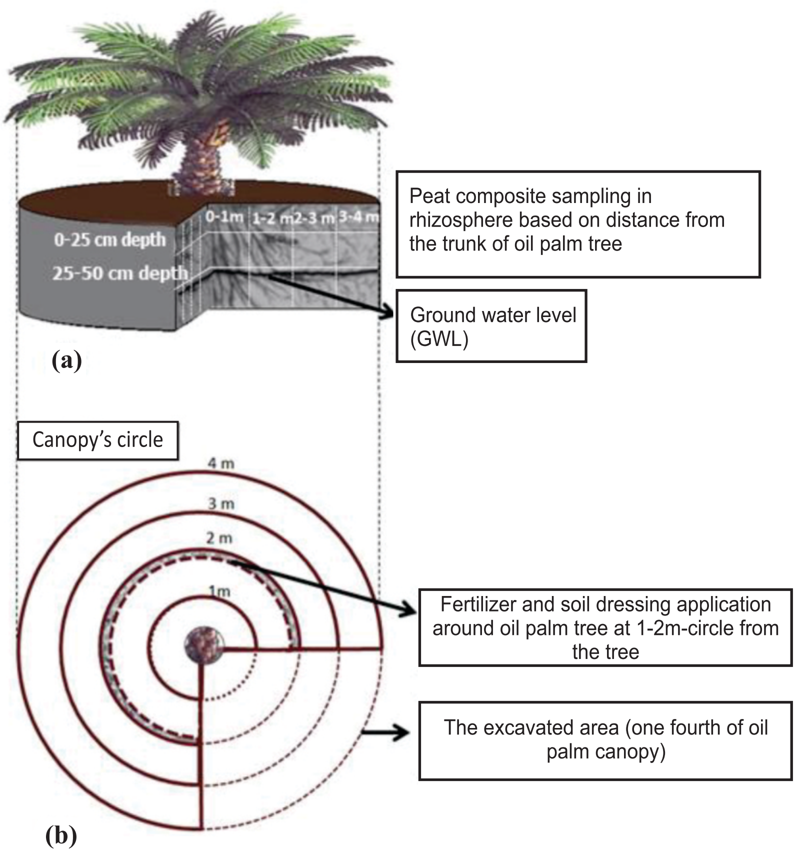

Figure 1 Peat composite sampling in the rhizosphere based on the distance from the trunk of an oil palm (a); fertiliser and mineral-soil dressing application around an oil palm tree (b)

Peat water content was determined using a volumetric water content, for which the water content was corrected by the bulk density of peat in each peat depth (Table 2). The ash content was done with the ashing method using a furnace at a temperature of 550°C. The pH (1:2) measurement of peat material (10 g of peat material: 20 ml of ion-free water) was performed by using a pH meter (pH 2700 Autech Instrument). Total macro nutrients (K, Ca, Mg) and micro nutrients (Fe, Cu, Zn) were determined using the wet destruction (extracting 60% $HClO_4$ and HNO_3) method, and the extracts were measured using the Atomic Absorption Spectrophotometer (AAS) Shimadzu AA-6300 for Ca, Mg, Fe, Cu, and Zn, whereas K was measured using the Flamephotometer Corning Flower 405r (Indonesian Soil Research Institute 2005).

Table 2 Bulk density (g/cm[3]) of peat in the oil palm rhizosphere based on peat thickness <3 and >3m, peat depth and plant age, and in the rhizospheres of the degraded peat forest and peat shrub

Peat depth (cm)	Peat Thickness <3 m Oil palm age (years)			Peat Thickness >3 m Oil palm age (years)			Degraded Forest	Shrub
	<6	6-15	>15	<6	6-15	>15		
0-25	0.1	0.26	0.11	0.09	0.11	0.1	0.17	0.17
25-50	0.09	0.09	0.1	0.09	0.09	0.09	0.11	0.16

Measured enzyme-activities included urease, phosphatase, β-glucosidase, and laccase activities. Urease activity was determined by measuring ammonium released using the non-buffered method, while phosphatase activity was determined to measure the release of phosphorous (P) from organic (P) using the p-nitrophenyl buffer method. β-glucosidase activity was determined to measure the breakdown of cellulose into glucose, using the β-glucosido-saligenin (salicin) method developed by Schinner *et al.* (1996). Laccase activity was determined to measure lignin degradation activity, using the 2.2-azinobis 3-ethyl-benzothiazoline-6-sulphonate (ABTS) method (Eichlerová *et al.* 2012). All data was analysed using MS Excel to obtain a descriptive analysis.

RESULTS AND DISCUSSION

pH Level and Water Content

pH level and water content affect biochemical reactions in the rhizosphere of peatlands. The water content of peat around the oil palm rhizosphere ranged from 10-120% (v/v) (Fig. 2). The water content of peat increased with increased root depth and distance from the tree, regardless of oil palm age (< 6, 6-15, and >15 years) on peat thicknesses of <3 and >3m (Fig. 2). This presumably occured because the loss of water in the deeper root zones was low due to the shallow water table while there was rapid water absorption in root zones near the tree. Increased water content was indicated by the solubilization of organic acids in the peatland, which would impact peat pH. Table 3 shows that pH had a significant negative correlation with water content. According to Neumann *et al.* (2000), plant roots secrete a number of organic acids, such as citric acid, to acidify the rhizosphere in mature plants.

Low pH in higher water contents decreased enzyme activity. As can be seen in Fig. 2, the peat pH was in the range of 3.0–4.0 in the rhizosphere and it was positively correlated with enzyme activity, particularly phosphatase, β-glucosidase, and laccase activities (Table 3). Blonka (2010) made the same observation that enzyme activity increases with increasing pH levels in peatlands. The pH value decreased with increasing distance from an oil palm tree, both in the peat layer of 0–25 and in 25–50 cm. This indicates that the low pH levels were the consequence of increased water contents in the deeper root zones.

The rhizospheres of vegetations in the degraded forest and shrubland had lower water contents (41-42% v/v) in peat layers at the depth of 0–25 cm than that in the depth of 25-50 cm (43-61% v/v). Peat layers at 25-50 cm had a higher ability to retain water. They had higher moisture contents due to the lower evaporation as well as the presence of capillary action coming from the peat's water table. Meanwhile, pH levels in the degraded forest and shrubland tended to be the same, ranging from 3 to 3.5. These levels, however, are lower than pH levels in the oil palm rhizosphere because fertiliser was added into the oil palm rhizosphere, as can be seen in Fig. 2, and the peat pH tended to increase at a distance of 1-2m from the tree.

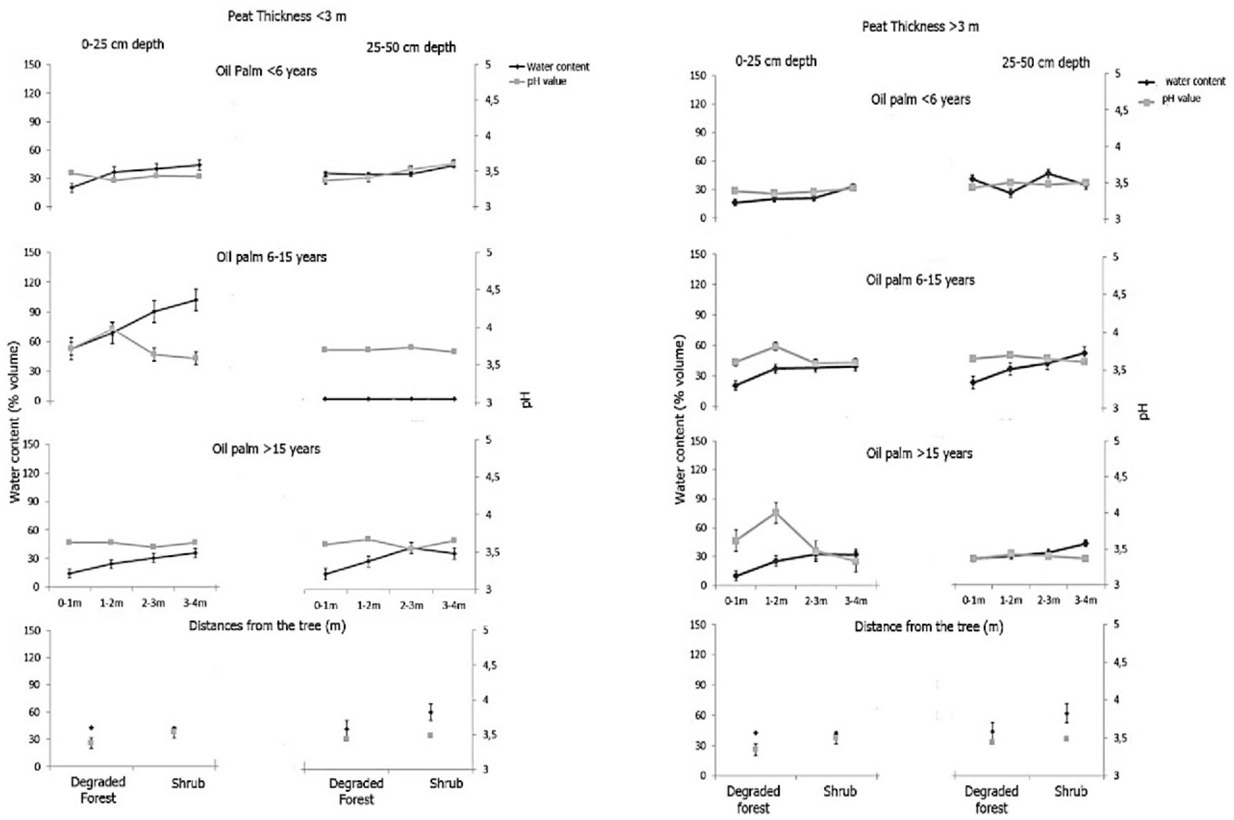

Figure 2 Volumetric water contents and the pH of the oil palm rhizosphere in peat thicknesses of <3 m and >3m by peat depth as well as distance from tree and plant age. The same measurements were taken in the rhizospheres of the degraded peat forest and peat shrub.

Table 3 Pearson's correlation coefficient test between the rhizosphere's enzyme activities, water contents, pH, ash contents, organic C and total nutrients in Riau's peatland

	Urease	Phosphatase	β-glucosidase	Laccase	Water content	pH	Ash content	Organic Carbon	K	Ca	Mg	Fe	Cu	Zn
Urease	1	0.231	**0.243***	**0.361****	-0.222	-0.200	0.213	-0.198	0.005	0.019	-0.084	**-0.242***	**-0.276***	-0.156
Phosphatase		1	**0.532****	**0.469****	**-0.619****	**0.318****	**0.584****	**-0.483****	-0.127	0.108	-0.012	**-0.487****	**-0.588****	-0.053
β-glucosidase			1	**0.815****	**-0.731****	**0.294***	**0.342****	**-0.307****	0.167	**0.397****	**0.286***	**-0.394****	**-0.540****	-0.231
Laccase				1	**-0.804****	**0.261***	**0.528****	**-0.452****	0.012	0.193	0.077	**-0.467****	**-0.618****	-0.121
Water content					1	**-0.387****	**-0.632****	**0.558****	0.020	**-0.263***	-0.150	**0.537****	**0.798****	0.125
pH						1	**.233***	-0.228	**-0.268***	**0.311****	0.042	**-0.254***	**-0.433****	-0.116
Ash content							1	**-0.723****	-0.076	-0.061	-0.164	**-0.294***	**-0.515****	**0.368****
Organic Carbon								1	-0.046	-0.037	0.106	**0.335****	**0.601****	-0.187
K									1	**0.556****	0.162	0.105	**0.537****	**0.337****
Ca										1	**0.734****	-0.059	-0.201	-0.196
Mg											1	0.052	0.005	-0.196
Fe												1	**0.678****	**0.489****
Cu													1	0.226
Zn														1

Note: *Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Organic Carbon and Ash Contents

Organic carbon contents in the oil palm rhizosphere in peat thicknesses of <3 and >3 m did not differ from organic carbon contents in the degraded forest and shrubland (50-60%) (Fig. 3). This indicates that organic carbon contents in the peat, after it was cleared and turned into a plantation, did not change much. Ash content in the oil palm rhizosphere in a peat thickness of <3 m did not differ from the ash content in a peat thickness of >3 m. Ash content increased with increasing plant age in a peat thickness of <3 m, and this might be due to the high quantities of nutrients absorbed by older plants and/or plants that have been continuously fertilized.

Organic carbon contents were found to have a significant negative correlation with enzyme activity (Table 3). Higher organic carbon contents support the deceleration of decomposition processes in peatlands, resulting in lower carbon emissions. A higher C/N ratio in peat is associated with reduced enzyme activity. Almeida *et al.* (2015) states that higher organic carbon contents and lower N contents in organic matter are caused by lower enzyme activity, resulting in slower decomposition processes.

Ash contents in the rhizosphere of oil palm >15 years were found to be higher than ash contents in oil palm <6 and 6-15 years. Increased ash contents might have been caused by increased plant age. On the other hand, ash contents decreased as the distance from the tree increased. This might have occured due to the application of fertilizer and a higher root density near the tree, causing a high rate of organic matter decomposition and the ash content to increase. Increased enzyme activity meant higher ash contents, as ash content showed significant positive correlation with enzyme activity. This indicated that enzyme activity increased the decomposition of peat with higher ash contents. Based on Boguta and Sokolowska (2014) higher ash content in peatlands meant faster mineralization processes.

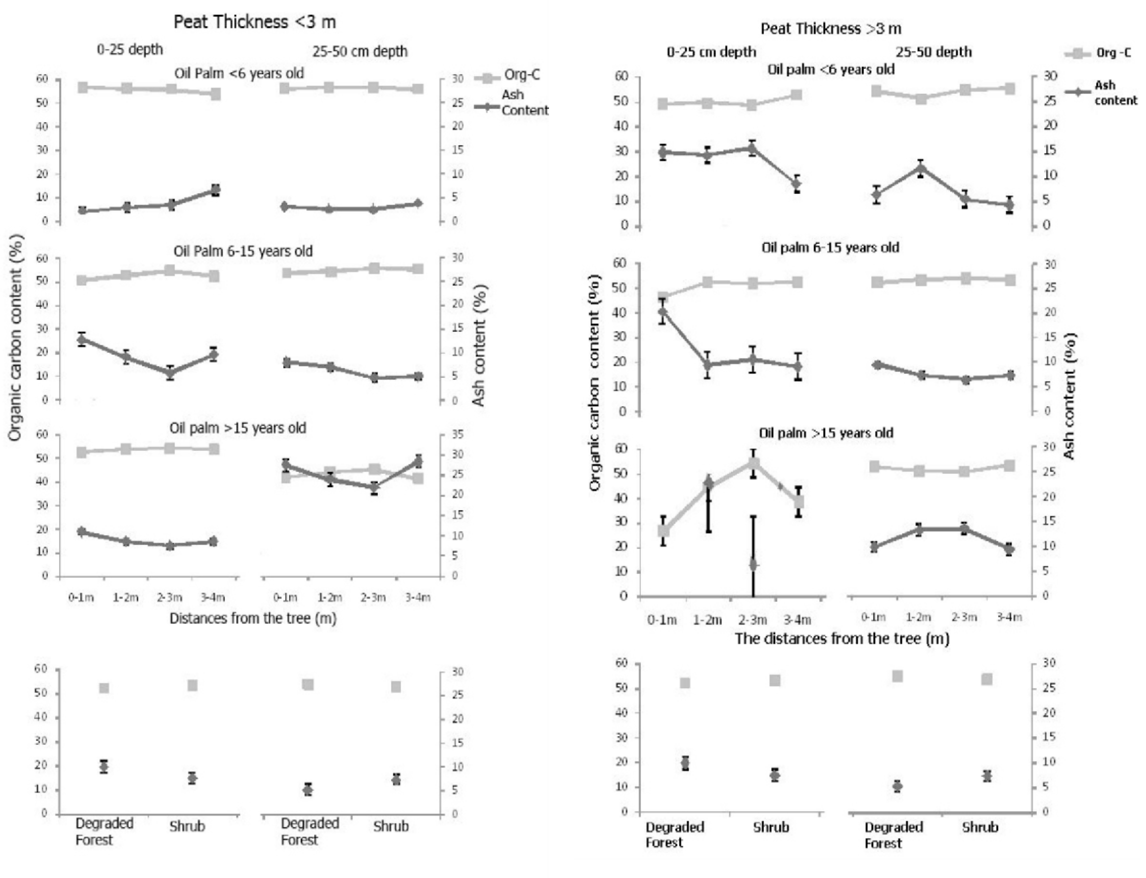

Figure 3 The organic carbon and ash contents in the oil palm rhizospheres by peat thickness (<3 m and >3m), by peat soil depth, by distance from tree and by plant age, as well as in the rhizospheres of the degraded forest and shrubland

Total K, Ca, Mg Contents

The total nutrient contents of K (30-150 mg/kg) and Mg (76-350 mg/kg) in the oil palm plantation rhizosphere for a peat thicknesses of <3 m and >3 m did not differ from total nutrient contents in the degraded forest and shrub vegetations. Nutrients in in the oil palm plantation rhizosphere tended to decrease with growing distance from oil palm trees. In contrast, the total content of Ca (100-3000 mg/kg) in the oil palm rhizosphere was higher than in the degraded forest and shrubland rhizosphere. Meanwhile, K and Mg contents were lower than the Ca content. K and Mg contents in peat layers of 0-25 cm did not differ from contents in peat layers of 25-50 cm. Total content of Ca decreased with increasing distance from an oil palm tree, particularly in oil palm aged <6 and >15 years (Fig. 4).

However, different results were obtained in oil palm aged <6 years in the 25-50 cm peat layer, where the Ca contents were found to be higher at distances of 3–4 m from the tree, which was caused by the limited extent of the roots of plants in this age group, in which there was concentration of root extent 0-1 and 1-2 m from the tree. Because of this, Ca absorption was minimized. In contrast, oil palm aged 6-15 years showed increased Ca contents at distances of 1–2 and 2–3 m from the tree, caused by the continuous application of fertilizer at a distance of 1-2 m from the tree (Table 1 and Fig. 1). Total Ca and Mg contents in peatlands were positively correlated with β-glucosidase, whereas the total K content showed no correlation with enzyme activity (Table 3). Ca and Mg treatment through dolomite-liming applications in oil palm plantations have the potential to increase peat pH, which results in increased enzyme activity. Szajdak *et al.* (2007) points out that active mineral material treatment can accelerate the decomposition of organic materials.

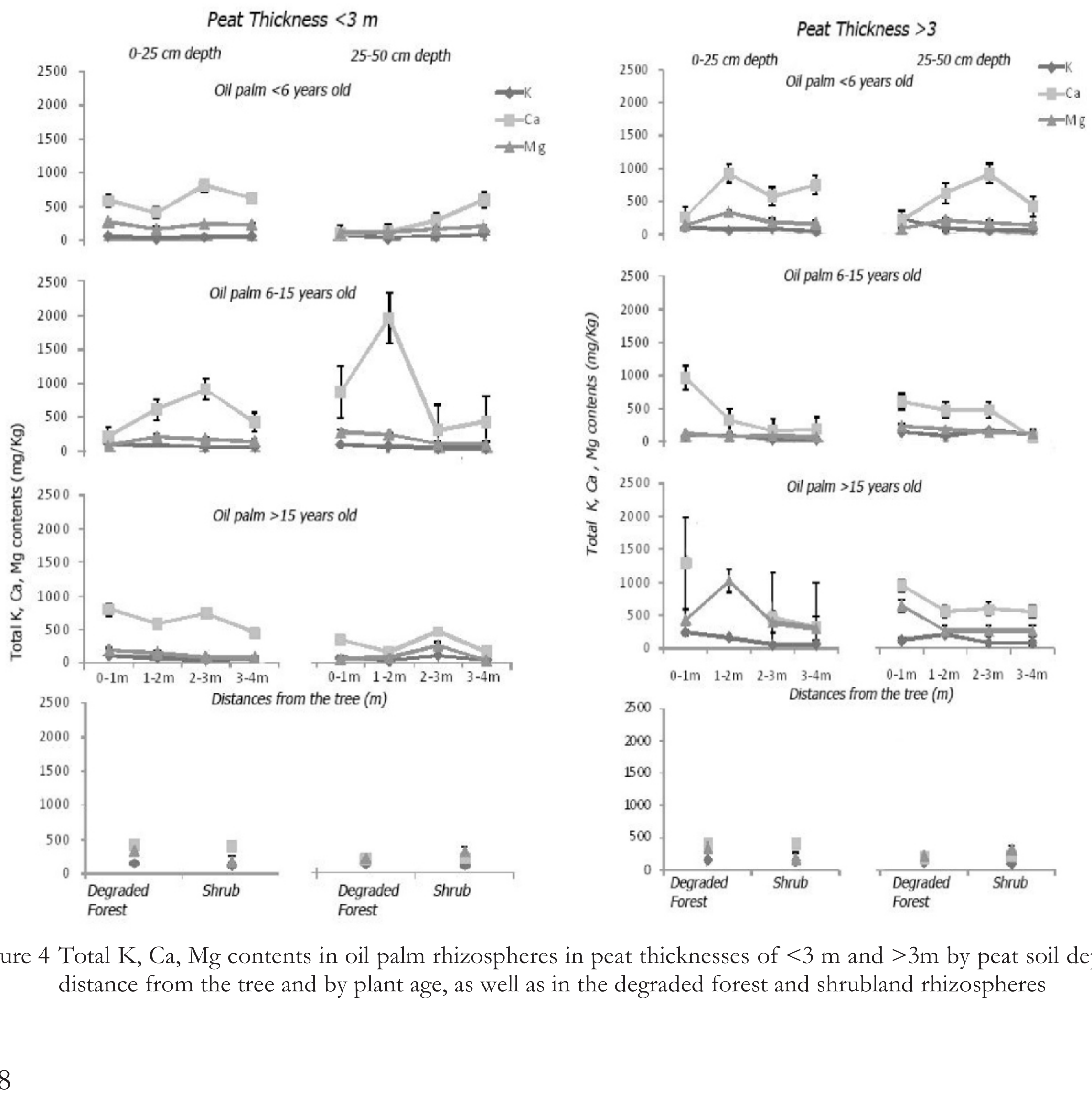

Figure 4 Total K, Ca, Mg contents in oil palm rhizospheres in peat thicknesses of <3 m and >3m by peat soil depth, by distance from the tree and by plant age, as well as in the degraded forest and shrubland rhizospheres

Total Fe, Cu, Zn Contents

Total Fe content in the oil palm rizosphere in a peat thickness of <3 m ranged from 300 to 700 mg/kg, whereas the total Fe content in a peat thickness of >3 m ranged from 350 to 2200 mg/kg (Fig. 5). The oil palm rhizosphere's total Fe content was higher in the forest and shrubland rhizopheres (100-350 mg/kg). The high level of total Fe may have come from the addition of mineral-soil dressings containing high Fe. A high Fe content might suppress enzyme activity as can be seen in Table 3, which shows a negative correlation between the total Fe content and enzyme activity (urease, phosphatase, β-glucosidase and laccase). The increase in total Fe was caused by the added Fe in mineral-soil dressing. Fe cation is the most reactive metal with organic acids to form a stable metal-organo complex (Hartatik 2012).

Cu contents were found to be in the range of 9-52 mg/kg in the peat depths of 0-25 and 25-50 cm, in peat thicknesses of <3 m and >3 m. The Cu contents were very low due to older plant age. Cu absorption by the roots of oil palm was thus increased. Meanwhile, Zn contents (1.5-22 mg/kg) were lower than Fe and Cu contents in the oil palm rhizosphere. Total Fe, Cu and Zn contents were increased at distances between 1 and 2 meters from the oil palm tree (Fig. 5). Fe, Cu, and Zn contents in the degraded peat forest and shrubland rhizospheres were lower than those in the oil palm rhizosphere. Fe, Cu, Zn contents in the oil palm rhizosphere were caused by the addition of Fe, Cu, and Zn through micro-nutrient fertilisers (Table 1) and mineral-soil dressing at distances of 1-2 m from the tree (Fig. 1). Fe, Cu and Zn cations are reactive metals that form metal organo-complexes with organic acids, which is hard to decompose (Tan 1993). Therefore, a high Fe content may suppress enzyme activity in decomposition processes, despite Fe being an enzyme activator.

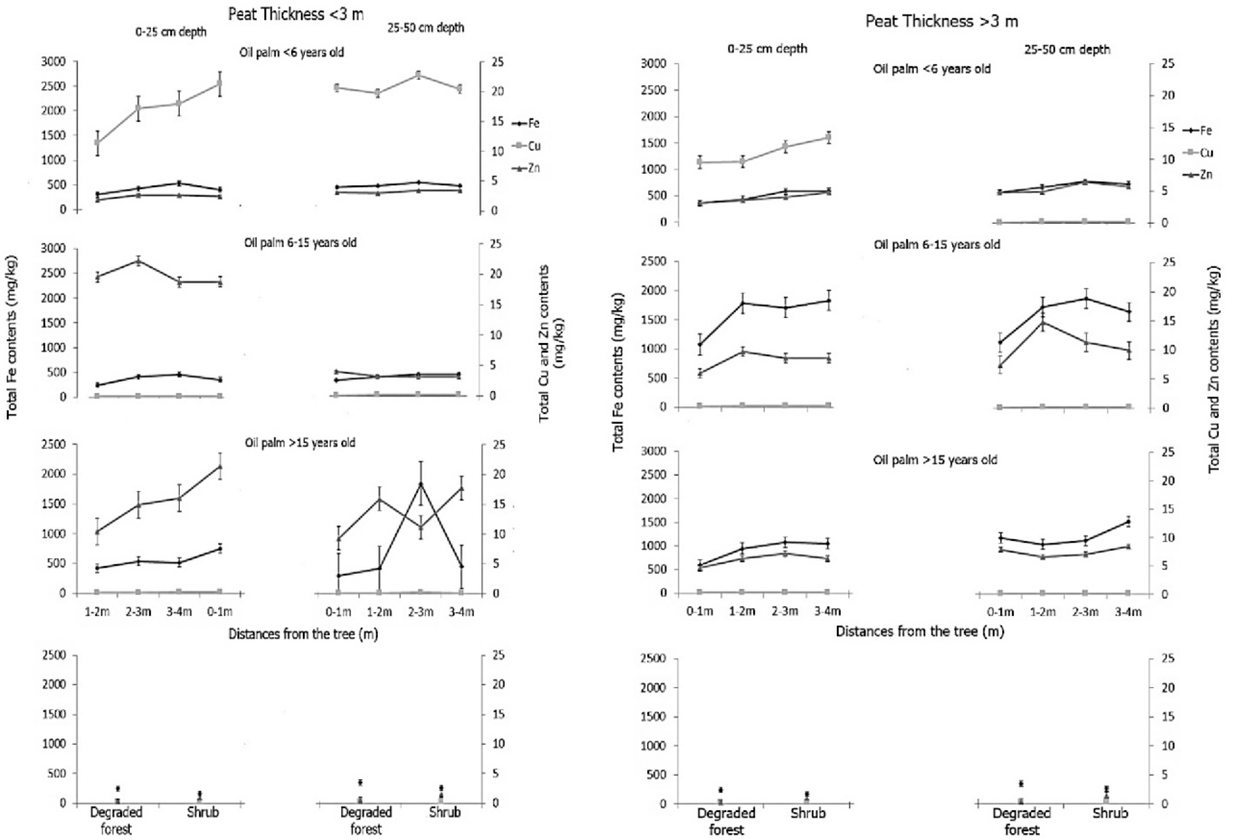

Figure 5 Total Fe, Cu, Zn contents in the oil palm rhizosphere, in peat thicknesses of <3 m and >3 m by peat soil depth, by distance from tree and by plant age, as well as in the degraded forest and shrubland rhizospheres

According to Ruggiero *et al.* (1996) in Stotzky and Bollag (1996), Cu and Fe function as catalytic centers for oxidoreductase enzymes (such as laccase, phenoloxidase, dehydrogenase) involved in redox reactions due to oxygen and hydrogen peroxide electron acceptors. Meanwhile, there was a significantly negative correlation between Zn contents and enzyme activity (urease, phosphatase, β-glucosidase, and laccase) because Zn is not a metal activator for such enzymes. However, Singh and Tabatabai (1978) found that Zn significantly affects rhodanase activity.

Enzyme Activity

Enzyme activity is related to the microbial activity of decomposing organic matter. Enzyme activity in peat thicknesses of <3 m and >3 m did not show variations (Fig. 6). But plant age may increase enzyme activity as well. In contrast, greater distance from the tree meant decreased enzyme activity, particularly in the range of 1-2 m from the tree. As known, fertilizer was continuously applied 1-2 m from the tree (Fig. 1), as shown in the increase in nutrients (Fig. 4, 5), which did not heighten enzyme activity and decomposition processes. In the 0-25 cm peat layer, enzyme activity was higher than in the 25-50 cm peat layer because the top layer of the peat was more oxidized so that it triggered the increase of microbial activity in producing the enzymes. Enzyme activity in the degraded forest and shrub vegetation rhizospheres was lower than in the oil palm rhizosphere. Laccase and β-glucosidase activities were higher than urease and phosphatase activities, which indicates that peat decomposition by the lignocellulolytic still occurred even though land had not been utilized.

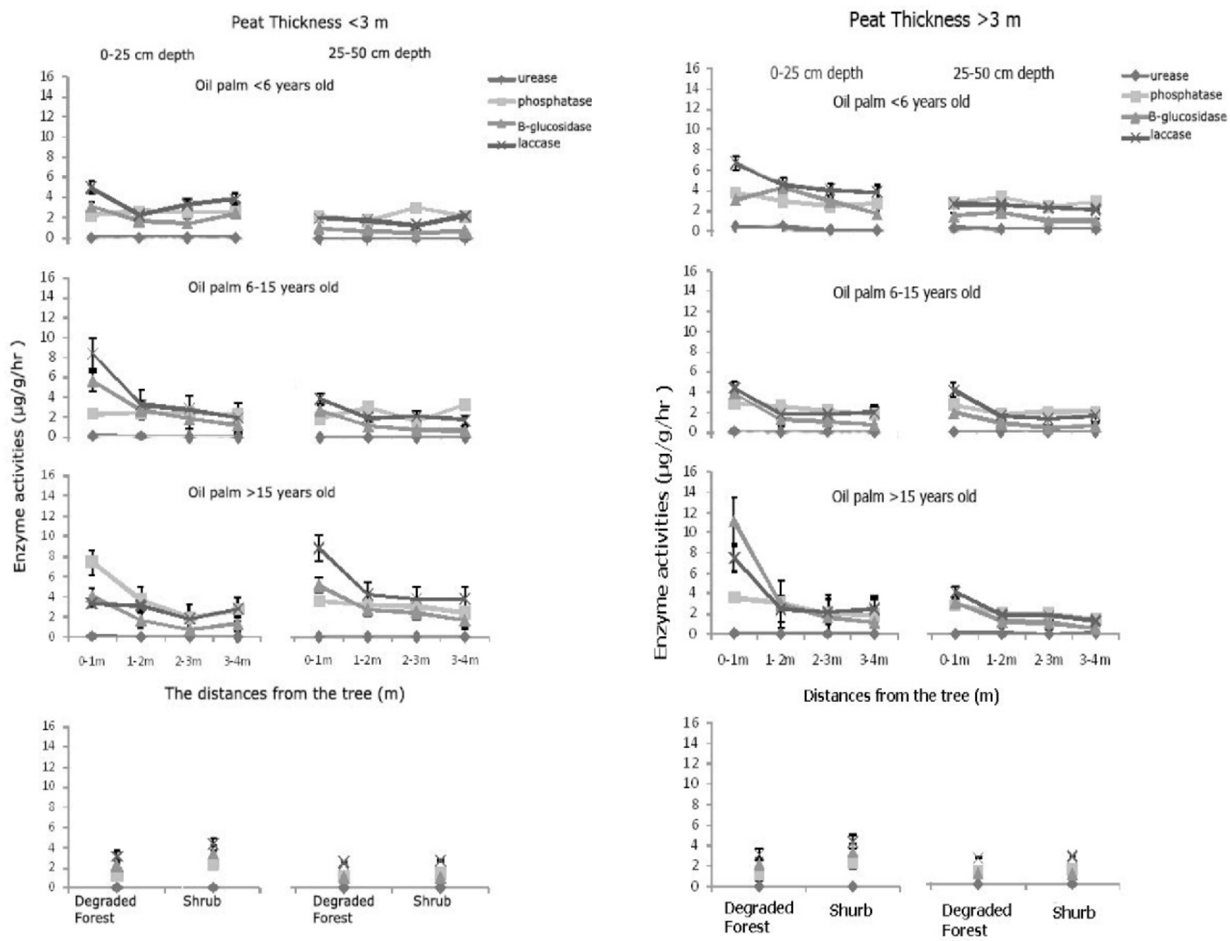

Figure 6 Enzyme activity in the oil palm rhizosphere, in peat thicknesses <3 m and >3m, by peat soil depth, by distance from tree and by plant age, as well as in the degraded forest and shrubland rhizospheres

Urease activity in the oil palm rhizosphere was very low (0.01- 0.5 µg/g/hr) compared to phosphatase, β-glucosidase, and laccase activities in peat thicknesses of both < 3 m and > 3 m with varying oil palm ages in the different peat layers (Fig. 6). Measured phosphatase activity ranged between 2 and 6 µg/g/hr. This shows that oil palm requires high levels of phosphate, as shown in peat thickness of <3 m, in which phosphatase activity was lower than in peat thickness of >3 m, and tended to increase with the age of the oil palm. On the other hand, phosphatase activity tended to decrease with increased distance from the tree. Oil palm can withstand growing at low P conditions by secreting phosphohydrolase (phosphatase) from its roots into the rhizosphere. The phosphohydrolase can convert organic phosphate into soluble inorganic phosphate, such as acid phosphatase, as a response to P deficiency (Lefebvre *et al.* 1990; Duff *et al.* 1994).

Urease and phosphatase activities were found to have a significantly positive correlation with β-glucosidase and laccase activities. However, urease and phosphatase activities had a significantly negative correlation with total Fe and Cu contents. In addition, phosphatase activity had a significant positive correlation with peat pH and ash content, and a significant negative correlation with water content and organic carbon content (Table 3). These enzyme activities indicate that peat decomposition can be suppressed by increasing water and organic carbon contents. According to Parham and Deng (2000) increased water content, low pH, the application of fertiliser and pesticide, as well as heavy metals and industrial waste, as part of soil and plant management, hamper enzyme activity.

The high Ca and Fe contents were obtained through fertilizer application and decomposition. Fertilizer application indirectly influenced peat characteristics, particularly peat soil pH. However, fertiliser application (K, Ca, Mg Fe, Cu and Zn) was not able to increase peat pH because of higher water and organic carbon contents. In regard to maintaining peat stability in the oil palm rhizosphere, this can be done by maintaining a high peat soil water content. According to Zhang *et al.* (2011), soil water is a factor that determines biochemical processes in C-transformations catalyzed by the β-glucosidase.

The presence of β-glucosidase and laccase activities indicates there was peat composition derived from cellulose-hemicellulose and lignin. Laccase activity was higher than β-glucosidase activity in the 0-25cm and 25-50 cm peat layers, which indicates that the peat decomposition of lignin was greater than that of cellulose and hemicellulose. β-glucosidase and laccase activities in the oil palm rhizosphere tended to decrease with increasing distance from the tree. β-glucosidase and laccase activities at a distance of 0-1 m from the tree were higher due to the high root activity and low peat water level causing a more oxidative peat environment, thus triggering an increase in microbial activity in the rhizosphere. Decreased enzyme activity at a distance of 3-4 m from the tree and in the 25-50 cm peat layer was caused by an increased peat water level and low pH. Otherwise, the peat pH ranged between 3 and 4, indicating that the peat's environment did not support increased enzyme activity for the decomposition of organic matter. In addition, the higher organic carbon contents suppressed enzyme activity, a fact that has to do with the optimum pH for enzyme activity. β-glucosidase activity is optimum in a pH 5.5 environment and urease in pH 6-7 (Parham & Deng 2000).

Lime and fertilizer treatments containing Ca and Mg in oil palm plantations can trigger increased enzyme activity. In contrast, the treatment of materials containing Fe and Cu in large quantities, such as the addition of mineral-soil dressings, can suppress enzyme activity, despite Fe and Cu being enzyme activators. Enzyme activity in the degraded forest and shrub vegetation rhizospheres did not show any difference from enzyme activity in the oil palm rhizosphere, particularly urease and phosphatase activities. Laccase and β-glucosidase activities in the degraded forest and shrub vegetation were higher than urease and phosphatase activities. This shows that peat can still decompose when the peatland is not in use.

CONCLUSION

Enzyme activity, as an indicator for peat decomposition processes, tends to decrease with greater distance from the tree and root depth.

Meanwhile, enzyme activity in the oil palm plantation rhizosphere increases the older the oil palm and the higher the peat's ash content. The total K content do not appear to be correlated with enzyme activity; however, total Ca and Mg contents are positively correlated with β-glucosidase activity. Total Fe and Cu contents in peat are negatively correlated with enzyme activity, while Zn contents are not correlated with enzyme activities. Enzyme activity in the rhizospheres of degraded forests and shrublands are generally lower than in oil palm rhizospheres. The application of fertilizer and mineral-soil dressing increases peat's nutrient contents but decreases enzyme activity. The decrease in enzyme activity is particularly influenced by low peat pH as well as Fe and Cu contents. Decreased enzyme activity translates into low decomposition in peat soils.

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